IN THE TEXT

Please add the new enclosed Abstract, attached to the end of the clean copy of the text, on a separate sheet.

The amendments proposed herein are to the text and drawings as filed in the Supplemental Amendment on the 23rd January 2006.

Where it occurs, change "uncooled" to 'un-cooled', and change the phrase "preferred embodiment" to 'selected embodiment'. In the amendments listed hereunder, deletions are shown between double brackets in strike-out, additions are shown underlined.

Amend the first paragraph under heading "Clarifications" as follows:

> By "un-cooled" is meant engines or pumps having ((~~restricted or no cooling, compared to general current production engine practice and includes engines with partial cooling~~)) <u>no mechanism for transfer of heat from combustion or working volume to ambient air. Such mechanism typically comprises a water jacket, pump, radiator and fan, or comprises a fan directing air over metal cooling fins or surfaces. Uncooled engines may have some form of charge cooling, wherein the temperature of the charge is reduced before it enters the combustion or working chamber.</u>

On page 6, after line 24 add new line, and change the following heading;

> <u>Figures 281 and 282</u> <u>show a splined telescopic drive shaft.</u>
>
> <u>SELECTED </u>((PREFERRED}} EMBODIMENTS

On page 11, amend the paragraph beginning on line 13 as follows:

> A selected embodiment of the engine is illustrated schematically in Figure <u>20</u>. It consists of a piston 1001 reciprocating between two combustion chambers 1002 at each end of a cylinder 1003 closed by two heads 1004, with a crankshaft 1006 outboard each head, the piston being connected by tensile members 1007 to both crankshafts. Optionally, the crankshaft will also function as a camshaft, actuating valves and optionally providing fuel delivery. The liquid elements for the charge may be delivered to the combustion chambers under pressures and temperatures higher than normal in conventional engines. The cylinder is at least partially surrounded by an exhaust gas processing volume 1008, with exhaust gas being conducted to the volume by alternate paths 1005 and 1009. Intake to the combustion chamber is via the crankcase. Surrounding the engine is a heavily <u>thermally</u> insulated casing 1010<u>, here functioning as structure enclosing volume 1008.</u> This configuration is suitable for four and two stroke embodiments, consuming fuel ranging from gasoline and similar lightweight fuels through diesel and heavier oil fuels to coal and other slurries or powders. Any engine

lubrication and / or bearing system may be employed, but optionally either gas or roller needle bearings are used, perhaps with water or other liquids, in the case of water preferably when the components are of ceramic material, as described later. The crank assembly is preferably so designed that any air bearings at least partially operate at a pressure equivalent to the charge pressure of forced induction, in the case of turbocharged, supercharged or force-aspirated engines. In the case of two stroke engines, the preferred arrangement is to exhaust gases via ports about the center of the cylinder. In the two cycle form illustrated schematically in Figure 21, pressurized air is ducted via crankcase 1275 and valve 1276, actuated optionally by combined crankshaft / camshaft 1277, to combustion chamber 1288 (fuel injection system not shown), displacing exhaust gas which exits the chamber via ports 1289 to exhaust gas processing volume 1290. Insulation 1010 extends around the engine of Figure 20, and is shown around the crankcases and engine of Figure 21. In another example of either a two- or four-stroke engine, Figure 22, the cylinder module 1271 is linked to a single crankshaft 1272 by tensile elements 1273 routed about guides / bearings / rollers and / or wheels 1274.

On page 24, amend the paragraph beginning on line 12 as follows:

In, for example, the case of compound engines, it may be desirable to use exhaust gas at high temperature and pressure to power a turbine, and to have a requirement for exhaust pressures to be low to facilitate two stroke combustion chamber scavenging. In such cases more than one exhaust processing volume may be incorporated in an engine. Figure 75 shows a schematic cross-section of a five cylinder engine with a high pressure, high temperature exhaust volume at 1308 with exit at 1309, surrounded by a low pressure, low temperature volume at 1310 with twin exits at 1311. Figure 76 shows a schematic layout of a compound system with a reciprocating engine 1312 having ambient air intake 1313, high pressure exhaust 1314 and low pressure exhaust 1315. High pressure exhaust is conducted to a high performance turbine 1316 to exit at 1317, at a pressure approximately matching that of low pressure exhaust 1315 with which it is mixed, and be conducted through low temperature turbine 1318 to emerge at 1319 as close to ambient pressure as possible. Optionally the turbines might be linked by shaft 1320. Figure 77 shows a cross-section of the engine of Figure 75, where high pressure exhaust ports 1321, closable by non-return valves 1322, communicate with high temperature and pressure exhaust reservoir 1323. The piston 1323A when at BDC/TDC unmasks ports 1324, communicating with low temperature and pressure exhaust reservoir 1325. Thermally insulating structure 1328 encloses both volumes 1323 and 1328. Figures 78 to 80 show a cylinder module made up of three elements, plus piston/rod assembly, valves, etc, and incorporating two exhaust processing volumes. The high pressure volume has four shaped snap-in non-return spring loaded valves 1326. Figure 78 is a long section and Figure 79 a cross section through the cylinder, while Figure 80 shows one valve 1326. The modules are assembled via tensile fasteners 1327, which also attach an evacuated thermally insulating cover 1328, separated from structural elements by trapped air space 1329. Modules are attached to each other via tensile fasteners 1327, with crank cover 1331 attached last at 1332. A similar construction, including tensile fasteners 1327, is shown also in Figures 68 and 69. On the expansion

stroke, the gases are at sufficiently high pressure to open the non-return valves 1326. As the piston exposes the low pressure system via the central port 1324, the pressure in the chamber drops sufficiently to cause the spring loaded valves 1326 to close. On the compression stroke pressures will be much lower and insufficient to re-open the valves.

On page 25, amend the paragraph beginning on line 5 as follows:

Regarding some of the stresses which may occur in the cylinder and head elements under high combustion chamber pressures, it is apparent that the tensile stress requirements of the components can be reduced if they are at least partly pre-stressed in compression when the engine is assembled. The forces of expansion will first have to counterbalance those loads before stressing materials to their design tensile limits. Calculations have shown that <u>there</u> are presently a range of commercially available ceramic materials having sufficient strength to be used to build the components of the invention, allowing for typical engineering safety margins.

On page 33, amend the paragraph starting on line 5 as follows:

For certain applications, including many pumps and / or compressors, rotary motion is not required. It is both simple and obvious to connect the end of the reciprocating piston/rod assembly to a pumping or compressing device. However, in many applications it will be preferred for engine final drive to have exclusively rotary motion, requiring a special link between the final drive and any reciprocating plus rotary movement of the piston/rod assembly (effectively the "crankshaft", actually the drive shaft). This can be accomplished by a coupling incorporating either a sliding bearing, such as in a splined propeller shaft, or an assembly incorporating roller, ball, needle or taper bearings. By way of example, <u>Figure 281 shows in cross-section and Figure 282 in elevation a schematic of vehicle-type co-axial nested drive shafts capable of reciprocating relative to each other, wherein rotational motion is transmitted via splines 3301 slidably mounted in corresponding grooves 3302. Range of reciprocal motion is indicated at 3303. As another example,</u> Figure <u>103</u> shows in cross-section and Figure <u>104</u> in elevation a schematic of a coupling between a piston/rod assembly 2078 and a final drive shaft 2079, for applications where loads are transferred in one rotational direction only 2080. Roller bearing races 2081 link planes 2082 inside the piston rod and on the shaft 2083. The connection between the two systems could be anywhere, including inside the piston segment of a piston/rod assembly.

On page 41, amend the paragraph beginning at the bottom of the page as follows:

If one is going to use one combustion chamber module to make engines of varying power and swept volume, then the gas passage(s) within the module (if any) should be so sized as to accommodate the gas flows of the largest engines likely to use that module. Figures <u>129</u> to <u>132</u> illustrate schematically various possible gas flow layouts, wherein 3126 indicates a multiplicity of equal sized toroidal combustion chambers, 3004

the moving component, 3007 the "fixed" housing (which, in all these embodiments, could also rotate), 3057 an enclosure or casing. A represents charge air volume, B high temperature and pressure exhaust, C lower temperature / pressure exhaust. Filamentary material is shown at 3128a. Porting is not shown, but can be as described elsewhere in this disclosure. Solid arrows describe gas flows through ports, dotted arrows show gas flow to and / or from transfer ports, or flows via passage or plenums as described elsewhere herein. Thermal insulation is indicated (schematically, like all other components) at 3127. In Figure 129, thermal insulation separates charge flow from hot components, charge flows into the combustion chamber, exhaust flows from it into a central exhaust gas reservoir. Obviously, the flows could be reversed, volumes A and B transposed, insulation moved to the interface of component 3004 and the central (now charge) gas reservoir or plenum. Figure 130 shows a system having transfer ports, indicated schematically at 3128. Here again, the flows could be reversed, volumes transposed, insulation repositioned. Figure 131 shows a layout where exhaust gas flows adjacent to the structural component of 3004 and 3007 are used to reduce heat flows (ie thermal gradients) across these components, with the center of the engine occupied by a mechanical system 3130. If 3130 were a fuel delivery system, this could serve to maintain liquid fuel under pressure at temperatures greater than boiling. A compressor and / or turbine system is indicated schematically at 3129 / 3134. In Figures 129, 131 and 132, casing 3057 comprises part of the structure defining volume A, while in Figure 131 thermal insulation 3127 is part of the structure defining volume C.

On page 43, amend the paragraph starting on line 7 as follows:

Figure 136 shows by way of example an engine assembly whose combustion chambers are of modular construction, wherein details A and B are half vertical sections along the different radii indicated in details C, D and E, which are cross sections through the planes indicated in the vertical sections. Component 3004 reciprocates relative to component 3007 and is shown at bottom dead center. Details C, D and E are shown with components 3004 and 3007 in different positions relative to each other, when the appropriate detail lines shown on the vertical sections A and B are in approximate alignment with each other. Identical ceramic reciprocating components are shown at 3155, with identical ceramic "housing" components shown at 3156. Charge circulates through volume 3157 and enters combustion chambers 3126 via inlet ports 3158, exits via exhaust ports 3159. Exhaust gas circulates through tubular volume 3160 and is spaced from outer enclosure 3057 by thermal insulation 3127, which functions as structure enclosing volume 3160. Exhaust gas circulates to some degree within spaces 3161, 3162. Since these communicate with the main exhaust gas circulation volume 3160, they serve to reduce thermal gradients in selected portions of the combustion chamber components. A gas bearing supplied by super-heated liquid is shown, schematically, at 3163. The respective components are assembled and fastened (preferably pre-loaded in compression) by means of tensile fasteners 3164 and 3165. Fasteners 3164 are located within the relatively cool charge flow volume and so are of conventional design, while fasteners 3165 are adjacent hot components 3156 (separating hot combustion chamber and hot exhaust volumes) and so are of tubular

design, the interior of the tube communicating with cooler volumes (say those containing charge air), this circulation of cooler gases through the interior of the fasteners serving to maintain their temperatures below the temperatures of components 3156. Loads are distributed along the rims or extremities of components 3155 and 3156 by means of load distributor elements 3166, 3167, 3168, 3169 which, in preferred embodiments, have additional other function(s) including possibly guide system, bearing and / or sealing components. They may also function as fuel delivery system or tribology system components. The matter of tribology and bearings as well as sealing is described elsewhere in the disclosure. Figure 137 shows a cross-section detail of an optional alternative to fastener 3165, wherein hollow tensile member 3170 does not fit tightly within component(s) 3156 but is separated from them by an insulating and / or elastomeric interlayer 3171, which could be of any suitable material, including ceramic wool. The engine illustrated in Figure 136 has four identical combustion chambers. It is obvious that other engines using components 3155 and 3156 can be constructed, including ones having two combustion chambers and, if volumes 3157 and 3160 are sufficiently large, engines with six or even more combustion chambers. Alternatively, components 3157 and 3160 can be used in other engines with four combustion chambers, for example, wherein heat exchanges are located within volume 3160 and the enclosure 3057 is therefore of larger diameter. When constructing different engines using standard components 3155 and 3156, it is probable that other components such as the fasteners, enclosures, etc will differ and be particular to each engine design. The combustion chambers illustrated in Figure 136 and elsewhere generally show an angle between wall and head / crown (angle Θ in Figure 412) of around 110° to 120°. In fact, the chambers could be designed with Θ any suitable angle, including 90°.

On page 44, amend the first paragraph as follows:

Figures 138, 139 and 140 show further examples of engines having combustion chambers of modular construction. The method of illustration is similar to that of Figure 136 (Figures 138, 139 and 140 each show a different engine), and both the size / configuration of the combustion chambers and the basic configuration of toroidal components 3155 and 3156 are similar in all four engines. Variations occur mainly in the gas flows and the methods by which loads to and from components 3155 and 3156 are transmitted. Because Figures 138 and 139 illustrate how two substantially different engines can be assembled using the same combustion chamber components, the details A, B. C, D and E of each figure are presented side by side, for purposes of comparison. Combustion chamber components 3155 and 3156, as well as the cross - section of fasteners 3164 (but not necessarily their length) are identical in both engines. Thermal insulation 3127 is deployed as indicated in both engines, as are load distributor elements 3166, 3167, 3168, 3169.

On page 44, amend the last two paragraphs by adding sentences to each as follows:

In the engine of Figure 138, charge air circulates in tubular volume 3172, enters the

combustion chambers via inlet port 3173, exits via exhaust port 3174 into high temperature / pressure exhaust gas circulation volume 3175. The exhaust gas passes to a turbocharger (not shown; the layout of Figure 132 would be suitable), and from there low temperature / pressure exhaust gas passes down the central volume 3176. Components 3155 are separated from each other and the load distributor elements by spacer rings 3177 and spacer plates 3178 having holes to accommodate volume 3175. Components 3156 are separated from each other and the load distributor elements by spacer rings 3179, each having a series of internal projections (see illustrations), and by inlet port rings 3180, each ring having a series of holes permitting the passage of charge air (see illustrations). Here the ring comprises an integral element having an upper rail and a lower rail separated by a series of posts (which accommodate the fasteners 3164), the transitions between them being rounded and smoothed. The tubular charge volume 3172 is enclosed by a casing 3181, here having within it passages 3182 containing circulating liquid, for the purpose of cooling the casing and therefore indirectly the charge. <u>Casing 3181 forms part of the structure enclosing volume 3172.</u>

The engine of Figure 139 has the same combustion chamber components 3155 and 3156 as that of Figure 138, and is therefore presumed to have the same stroke and similar inlet and exhaust port openings, ports shown at 3173 and 3174, respectively. However, the gas flow is different, charge flowing in central volume 3183 to the inlet port via passages 3184 and transfer port 3185, thereafter leaving the combustion chambers via exhaust port 3174 into essentially tubular exhaust processing volume 3175. The difference from the engine of Figure 138 has been achieved only by substituting spacer plate(s) 3178 with a series of eight smaller but taller ring-shaped spacer plate(s) 3186, each also able to accommodate volume 3175, and by substituting the inlet port ring(s) 3180 with taller transfer port ring(s) 3187. Note that spacer elements 3177 and 3179 remain unchanged. Since the gas flows are different, outer casing 3181 can be eliminated. In both engines there are located within or adjacent to components 3156 special volumes 3188 which communicate with volume 3175 and will therefore also contain exhaust gas. As previously, the objective of volumes 3188 is to reduce combustion chamber heat loss through components 3156. <u>Portions of components 3155 and 3186 are part of the structure enclosing volume 3155.</u>

On page 45, amend the first paragraph starting there as follows:

The engine of Figure 140 illustrates alternate ways of assembling / fastening / mounting modular combustion chamber components. Components 3189 and 3190 are similar to those illustrated previously, as are volumes 3188 housing or permitting the passage of exhaust gas. Here charge travels within tubular volume 3172 via inlet port 3173 to the combustion chamber; exhaust exits via exhaust port 3174 to central tubular exhaust gas volume 3191. <u>Outer casing 3181 comprises part of the structure enclosing volume 3172</u>. Instead of using conventional tensile fasteners (such as 3164 in Figures 138 and 139), this engine is assembled by means of pierced tubes. Inner tube 3192 is continuously threaded on its outer surface. Load distribution rings(s) 3193 are threaded onto the inner tube 3192, and once in final position secured by means of locator pins or keys 3194. The rings support components 3189, which are further restrained by sleeves 3195

of rectangular form with rounded corners, inserted into pre-formed holes in tube 3192, and restrained by means of pins 3196. Exhaust gas passes from port 3174 through this sleeve 3195 to volume 3191. In a similar manner, components 3190 are supported by means of load distribution ring(s) 3197 threaded within outer tube 3198, and when in final position secured by means of locator pins or keys 3194. Components 3190 are further restrained by circular sleeves 3199 threaded into pre-formed holes in outer tube 3198 and restrained by means of pins 3196. Inlet charge passes from volume 3172 through this sleeve 3199 to inlet port 3173. Insulation 3127 within and against outer tube 3198 prevents heat loss from exhaust gas in volumes 3188. An outer casing 3181 defines volume 3172. In an alternative embodiment, illustrated only in details B and E, the casing has a multiplicity of projections 3200 located in the charge air flow, and is made of material having good thermal conductivity, for the purpose of transferring heat from the charge to beyond the casing 3181 (a form of after-cooling). This device is particularly useful in situations where the fluid surrounding the casings is at low temperature, say under water in marine applications or at high altitude in aircraft applications. The projections 3200 are shown schematically only; they can be of any configuration and integral with the casing or attached to it in any way. Exhaust gas reaches volumes 3188 associated with components 3189 from volume 3191 via holes 3201 in inner tube 3192, which is of varying thickness in cross section, stiffening ribs 3202 running vertically or longitudinally on the inside of the tube between the exhaust sleeves 3195. Within each rib are two capillary fuel tube systems 3203 (one to supply all the chambers moving 3004 in one direction, the other for the chambers moving 3004 in the other direction), which communicate with the combustion chamber via load distribution ring(s) 3193. Here, two tubes 3203 are shown in each longitudinal rib, however any twin system of tubes and / or galleries may be used, supplying the chambers via ring(s) 3193 and / or directly. The fuel supply need not be within the tube, but could be in fuel lines within volume 3191 to pierce 3192 via connectors, couplings, etc. Fuel delivery is here shown associated with the inner tube; it could be equally associated with the outer tube 3198. A similar system of tubes / passages / fuel lines could be used to provide fluid used for tribological purposes to any desired location within the engine. In Figures <u>138</u> and <u>139</u>, the fasteners were attached to load distributor elements 3166 to 3169. Here, the outermost rings 3197 could be identical to an inner ring 3197, or they could be integral with a component 3204 having another function, such as bearing, gas-seal, guide system element, as indicated in the diagram. To prevent differential rotation between components 3189/3190 and their respective support rings 3193 / 3197, the support surfaces of the rings may have projections and/or undulations matching indentations or undulations on the corresponding support surfaces of the combustion chamber components. In schematic illustration, Figure <u>141</u> shows elevationally part of a ring having support surface undulations, while Figure <u>142</u> similarly shows part of a ring having projections or nipples which also have fuel delivery tubes.

On page 47, amend the last paragraph as follows:

The different concepts in this disclosure can be combined in any way. For example, any single combustion chamber can be deployed each side of a guide system or a conventional crankshaft. Any combination of combustion chambers can be arranged

each side of the above mentioned drive or guide devices, the numbers of the chambers and their configuration not necessarily being the same on each side. In a further example, the combustion chamber grouping of Figure 94 can be arranged on one side or either side of a different drive system, or a power take-off (Figure 128). Separate retractable guide systems can be associated with each of the differently sized chambers, either the largest or smallest chamber closest to the drive, to provide engines having three or six toroidal combustion chambers of three different sizes. In a further example, the combustion chamber and pumping chamber combination of Figure 113 can be arranged on one or both sides of a crankshaft. Generally, it will be sensible to group combustion chambers in coaxial pairs, with each of a pair on opposite sides of a central flange forming part of a reciprocating system, and / or each side of a more or less centrally located guide system(s) or crankshaft(s). However, multiple chambers need not be either equal or coaxial, and could be deployed in any fashion about a crankshaft or other drive or guide system. Where appropriate, "sinusoidal" toroidal chambers may be used (such as are shown in Figures 109 through 115, for example), instead of the "regular" toroidal chambers generally illustrated. The "regular" toroidal chambers may be defined as surrounding or containing within them a component which just reciprocates, or which both reciprocates and is caused to rotate by a guide system. "Sinusoidal" toroidal chambers may be defined as having opposing surfaces, each of which ((~~are~~)) is not on a straight plane but ((~~have~~)) has a three dimensional form of regular configuration. By regular, it is meant that an entire surface has a form consisting of a sub-form which repeats (but the sub-form may also comprise the whole form in special cases), this sub-form (or whole form) having a wave-like configuration, the wave being defined by the sine curve or any other mathematical formula. Here, wave form is meant to include a series of apexes linked by straight lines or planes. Crankshafts can be used singly in any location or they can be used in multiples, as shown schematically in Figures 20 to 32. Toroidal combustion chambers or pumping volumes can be used in combination with non-toroidal combustion or pumping chambers. There need be no crank or guide or any drive system. Figure 134 shows an arrangement wherein a toroidal combustion chamber 3146 drives a piston 3145 which works a pumping volume 3147. In operation, combustion chamber expansion causes pumped fluid to exit volume 3147 in direction 3148 via non-return valve 3149, and combustion chamber compression is effected by pressure from fluid entering volume 3147 from direction 3150 via non-return valve 3151. (Such a machine could be used to give pressure boost in pipe flows.) Generally in this disclosure, like numbered parts have similar characteristics and / or functions.

In addition, please amend the first full paragraph on page 7 as follows:

In a basic embodiment, the moving parts are of metal of a construction and type conforming to current practice, with the possible exception of the exhaust valve. Figure 1 shows by way of example a schematic cross-section of an un-cooled engine, having a ceramic engine block 400, a ceramic cylinder head ((~~block~~)) 401, camshaft 402, valve 403, port 404, cam cover 405, sump cover 406, fuel delivery device 407, crankshaft 408, connecting rod 409, piston 410 and combustion volume 411. All moving parts are metal, except the ceramic exhaust port. A seating detail at the port is shown

in Figure 2, where valve 403 seats against compressible seal 412, optionally lubricated by passage 413, in cylinder block 401. Figure 3 shows an alternative detail, where valve 403 seats against ring 414 slidably mounted in groove 415 containing, between ring and groove floor 416, a compressible cushion 417, lubricated by optional passage 413, the cushion forcing the ring slightly outward when valve is lifted. If necessary the compressible material may be bonded to groove floor and / or ring member, to better prevent the latter leaving the groove. The compressible member may be constructed out of ceramic fiber and serves as a shock absorber at valve closure, ceramic not being as ductile and resistant to certain types of mechanical shock as metal. The piston can be of a heat resistant alloy such as nickel-chrome, having ceramic piston rings. Finning at the bottom of the piston (not shown) can give some cooling to the crank volume, which may be part cooled through the sump. The piston could equally be manufactured of ceramic or other suitable non-metal. Lubrication would be by any suitable substance, including those mentioned elsewhere. If lubrication were such as to easily pick up particles of say ceramic, which would damage softer metal bearing surfaces, then metal piston rings might be used to ensure that wear produces powder of the softer material, metal. Such an engine would be considerably lighter than conventional units, especially if construction used light, high alumina content ceramics. Considering also the elimination of cooling mechanics plus fluid, the overall large weight reduction would further contribute to fuel savings, where the un-cooled engine is used in vehicles. The construction of engine blocks at least partly in insulating material would greatly assist in the reduction of noise and vibration, thereby providing additional social benefit. Gaskets between ceramic components may be of ceramic such as asbestos mat.

Respectfully submitted,

Mitja Victor Hinderks.

Sole inventor, applicant and power-of-attorney of record.